

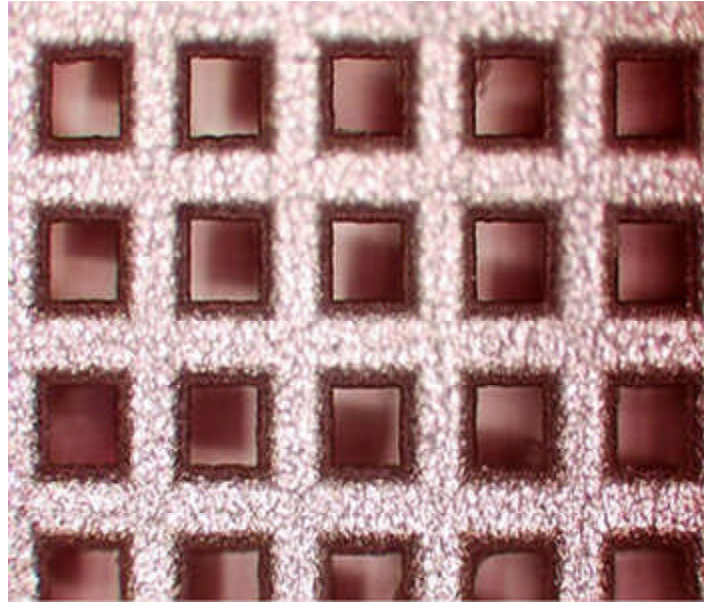
# **Microelectromechanical System (MEMS) Device Being Developed for Active Cooling and Temperature Control**

High-capacity cooling options remain limited for many small-scale applications such as microelectronic components, miniature sensors, and microsystems. A microelectromechanical system (MEMS) using a Stirling thermodynamic cycle to provide cooling or heating directly to a thermally loaded surface is being developed at the NASA Glenn Research Center to meet this need. The device can be used strictly in the cooling mode or can be switched between cooling and heating modes in milliseconds for precise temperature control. Fabrication and assembly employ techniques routinely used in the semiconductor processing industry. Benefits of the MEMS cooler include scalability to fractions of a millimeter, modularity for increased capacity and staging to low temperatures, simple interfaces, limited failure modes, and minimal induced vibration.

The MEMS cooler has potential applications across a broad range of industries such as the biomedical, computer, automotive, and aerospace industries. The basic capabilities it provides can be categorized into four key areas:

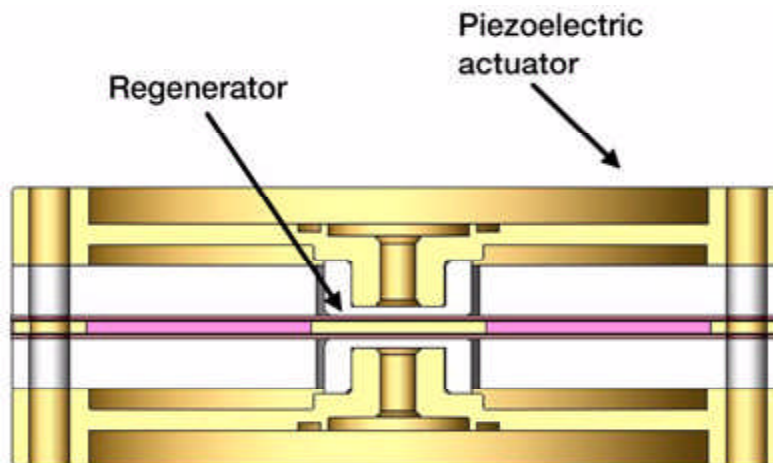
1. Extended environmental temperature range in harsh environments
2. Lower operating temperatures for electronics and other components
3. Precision spatial and temporal thermal control for temperature-sensitive devices
4. The enabling of microsystem devices that require active cooling and/or temperature control

The rapidly expanding capabilities of semiconductor processing in general, and microsystems packaging in particular, present a new opportunity to extend Stirling-cycle cooling to the MEMS domain. The comparatively high capacity and efficiency possible with a MEMS Stirling cooler provides a level of active cooling that is impossible at the microscale with current state-of-the-art techniques. The MEMS cooler technology builds on decades of research at Glenn on Stirling-cycle machines, and capitalizes on Glenn's emerging microsystems capabilities.



*Regenerator microphotograph showing 100- $\mu$ m openings.*

A working model of a MEMS cooler device is being assembled and tested at the Johns Hopkins University Applied Physics Laboratory under a Glenn grant. Initial testing will focus on MEMS regenerator performance. The 1- by 1-cm regenerator was fabricated for NASA by Polar Technologies. Commercial (non-MEMS) piezoelectric actuators will be used to drive the compression and expansion diaphragms, which are the only moving parts of the device. The diaphragms are deflected toward and away from the regenerator region in phase-shifted sinusoidal fashion to produce the Stirling cycle. Expansion of the working gas directly beneath the expansion diaphragm in each cycle creates a cold end for extracting heat, whereas compression at the other end creates a hot region for dissipating heat. Heat is transferred to and from the working gas as it is forced through the regenerator region by the moving diaphragms.



*MEMS regenerator with piezoelectric actuators.*

Following regenerator characterization tests, the piezoelectric actuators will be replaced

with MEMS electrostatic comb-drive actuators fabricated at Johns Hopkins in preparation for performance tests of a full working model in 2003.

Analysis of the MEMS cooler has been completed and indicates a theoretical performance that is an order-of-magnitude improvement over existing state-of-the-art techniques for cooling small-scale components. Research on the MEMS cooler is a collaborative effort of Glenn and Johns Hopkins. A patent for this technology (Microscalable Thermal Control Device, U.S. Patent 6,385,973 B1) was granted in May 2002.

**Find out more about the research of Glenn's Thermo-Mechanical Systems Branch**  
**<http://www.grc.nasa.gov/WWW/tmsb/>.**

## **Bibliography**

Moran, Matthew E.: Multidisciplinary Analysis of a Microsystem Device for Thermal Control. Proceedings of the 11th Thermal and Fluids Analysis Workshop. NASA/CP-2002--211486, 2002, pp. 173-186.

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